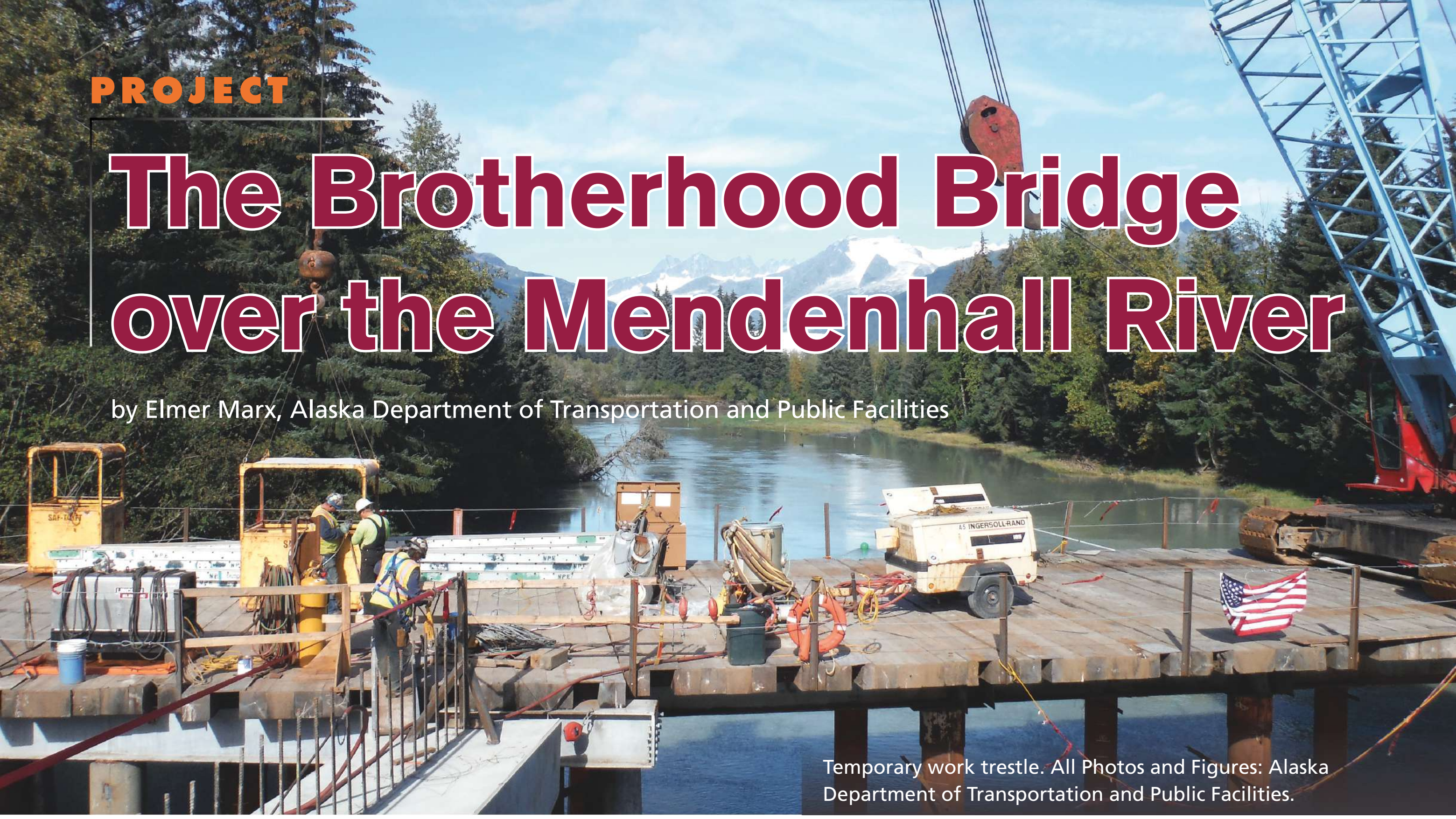
PROJECT

The Brotherhood Bridge over the Mendenhall River

by Elmer Marx, Alaska Department of Transportation and Public Facilities



Temporary work trestle. All Photos and Figures: Alaska Department of Transportation and Public Facilities.

The Brotherhood Bridge (also known as the Mendenhall River Bridge) is located near Juneau, Alaska, about five miles downstream of the Mendenhall Glacier. The project, which has interesting historical connections to the region's Native Alaska community, faced several unique design challenges not often encountered outside of Alaska and incorporates many features commonly used by the Alaska Department of Transportation and Public Facilities (AKDOT&PF).

History

Five bridges have been built to cross the Mendenhall River at this location. The first road crossing at the river, a timber trestle, was constructed in 1903 for a total cost of $1700. The timber trestle was reconstructed in 1919 and then replaced with a single-lane, two-span steel truss in 1931. In 1965, the fourth bridge, a two-lane, three-span continuous steel girder structure, was built and named the "Brotherhood Bridge" to commemorate the 50th anniversary of the Alaska Native Brotherhood (ANB).

Roy Peratrovich Jr. was an engineer for the Alaska Department of Highways team that designed the 1965 structure. He is a Tlingit of the Raven Lukaax.ádi clan, the first Alaska Native person registered as a professional civil engineer in Alaska, and the son of prominent Alaska Native civil rights leaders Elizabeth and Roy Peratrovich Sr. In honor of the ANB anniversary, Peratrovich Jr. sculpted 10 bronze medallions with the ANB crest and imagery, which were incorporated into the bridge rail of the 1965 structure.

The bridge served the community well for about five decades. But, as the weight of trucks increased, traffic demands grew, and design code requirements became more stringent, the need for a replacement bridge became apparent. Construction of the replacement bridge began in April 2014. The new bridge, which was rededicated in October 2015, retains the name and decorative bronze medallions that are a key part of the Brotherhood spirit.

Geological and Hydrological Considerations

The Mendenhall Glacier is viewed by more than 500,000 tourists every year. Currently, the face of the glacier is located about 1.5 miles from the Mendenhall Glacier Visitor Center; however, several hundred years ago, the face of the glacier was located near the bridge site. As the glacier has retreated, the surrounding ground surface has risen due to isostatic glacial rebound. At the bridge's location, the ground surface is rising at a rate of about 1 in. per year. Consequently, the river is incising and

profile

BROTHERHOOD BRIDGE (MENDENHALL RIVER BRIDGE) / JUNEAU, ALASKA

BRIDGE DESIGN ENGINEER: Alaska Department of Transportation and Public Facilities Bridge Section, Juneau

PRIME CONTRACTOR: Orion Marine Group, Anchorage, Alaska

PRECASTER: Concrete Technology Corporation, Tacoma, Wash.—a PCI-certified producer

GEOTECHNICAL AND FOUNDATION CONSULTANTS: Jacobs (formerly CH2M Hill), Bellevue, Wash.

OTHER MATERIAL SUPPLIERS: Formliner (enlarged version of medallions): Spec Formliners Inc., Santa Ana, Calif.; elastomeric bearing pads: Seismic Energy Products LP, Athens, Tex.

Ten bronze medallions from the 1965 bridge commemorating the 50th anniversary of the Alaska Native Brotherhood were reused in the new bridge railing. The sculptor, Roy Peratrovich Jr., was a member of the Alaska Department of Highways team that designed the 1965 structure. He was the first Alaska Native person registered as a professional civil engineer in Alaska.

lowering the streambed surface below the bridge—that is, the exposed length of the piers will increase over the life of the bridge. This phenomenon had to be considered when planning for pier scour over the design life of the structure.

The recession of the Mendenhall Glacier has resulted in several unusual flood-like events that have followed the outbursts of glacier-dammed lakes. Such events are known by the Icelandic term *jökulhlaups* (pronounced "yo-KOOL-lahps"). The Mendenhall River jökulhlaups have caused floodwater surface elevations above those of the 50-year flood event and accelerated erosion along the riverbanks (which are partially lined by residential structures). Predicting these events can be difficult given the uncertainties of lake volumes, fill rates, glacier buoyancy, and other contributing factors. In addition to the transport of large wood debris, jökulhlaup floodwaters may include large chunks of ice.

The previous bridge substructure was founded on driven steel H-piles that penetrated up to 70 ft beneath the streambed. The effects of local pier scour, isostatic glacial rebound, and jökulhlaups undermined the pier footings of the previous bridge and were among the contributing factors for why it had to be replaced.

Geotechnical and Seismic Considerations

Much of Alaska's coastline is located on the Pacific "Ring of Fire." Consequently, Alaska is subjected to frequent and strong ground shaking. Although the seismic hazard at the bridge site (peak ground acceleration ~0.2*g* for the 7% probability of exceedance in the 75-year design event) is not particularly large compared to other places in Alaska, it was predicted to be enough to generate soil liquefaction below the bridge.

Geology at the bridge site is composed of over 150 ft of nonplastic silts and sands. Blow counts from standard penetration tests within the silts and sands were generally under 15 blows per foot; cone penetrometer test soundings and shear wave velocity measurements confirmed very soft to loose soil conditions.

Preliminary analyses showed that sediment liquefaction could be triggered at depths in excess of 100 ft and might result in free-field lateral spreading of between 4 and 6 ft at bridge abutments and center piers. At this level of deformation, the bridge could not be guaranteed to satisfy the American Association of State Highway and Transportation Officials (AASHTO) requirements for noncollapse. Therefore, some form of liquefaction mitigation was required.

ADOT&PF worked with CH2M Hill (now Jacobs) to examine various approaches to address the seismic demands at the site. Pseudostatic slope stability analyses using limit equilibrium methods were conducted to evaluate the seismic stability of the abutment during and immediately after the design seismic event.

The response was evaluated for two conditions. The first considered flow failure. In this case, the soil liquifies and loses strength when the ground is not shaking. This case has been observed when liquefaction is slow to develop, sometimes occurring several minutes after the end of the earthquake. The second condition considered lateral spreading, where reduction in soil

Installing the precast, prestressed concrete decked bulb-tee girders during nighttime construction. During the summer in Alaska, there is still daylight or twilight during "nighttime" construction.

ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES, OWNER

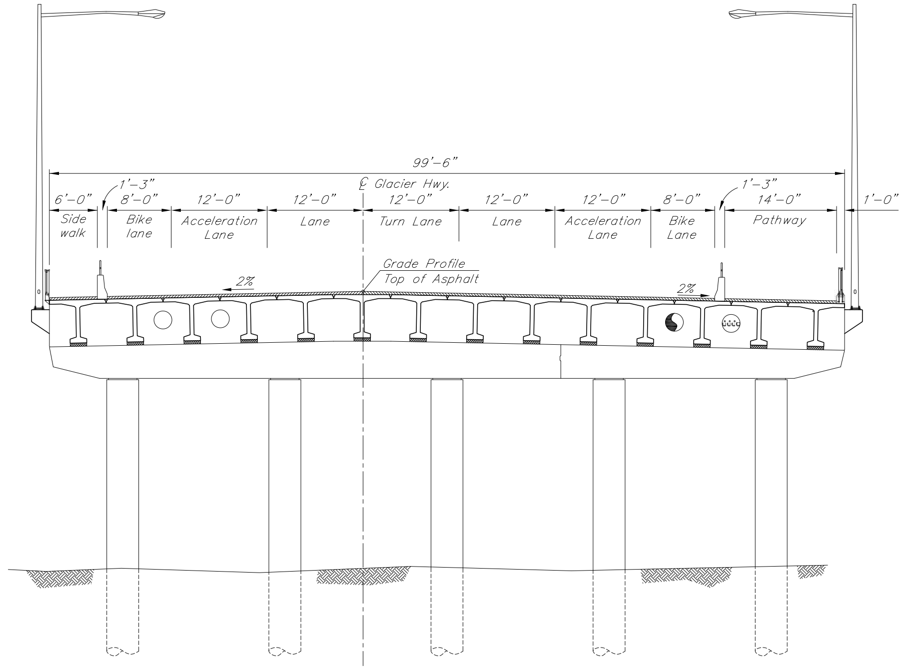
BRIDGE DESCRIPTION: Three-span, prestressed concrete decked bulb-tee girder superstructure on reinforced-concrete-filled steel pipe pile extension bents

STRUCTURAL COMPONENTS: Forty-two 65-in.-deep decked bulb-tee girders; twenty-eight 2-ft-diameter reinforced-concrete-filled steel pipe piles at the abutments; ten 4-ft-diameter reinforced-concrete-filled steel pipe piles at the piers; cast-in-place concrete pile caps, diaphragms, traffic barriers, and approach slabs

BRIDGE CONSTRUCTION COST: $11 million ($294/ft^2)

AWARD: Outstanding Project of the Year Award, American Society of Civil Engineers, Alaska Section, Juneau Branch strength and ground shaking occur in combination. These analyses were performed without consideration of the "pinning" effects from the abutment or pier piles. Both circular and noncircular failure surfaces were evaluated.

Once the "free field" condition had been better quantified, the option of pile pinning was examined. In the pile-pinning approach, restraint is provided by the bridge superstructure (acting as a strut) and by the lateral resistance of reinforced-concrete-filled steel pipe piles displaced during slope movement, which results in stabilizing forces to slope movement. This approach provided bridge stability without the need for expensive ground improvement work. Preliminary assessments found that the depth and location of ground improvement would cost over $2 million. Given the costs, environmental constraints, and schedule limitations, pile pinning was evaluated to provide a cost-effective approach for the liquefaction hazard. The use of pile pinning has become a frequent approach for other AKDOT&PF bridge projects.



Typical section of the precast, prestressed concrete decked bulb-tee girder superstructure that is supported on reinforced-concrete-filled steel pipe pile extension bents.

Design and Construction

The Brotherhood Bridge is located near a popular pedestrian trailhead and area for viewing/photographing the Mendenhall Glacier. The new three-span structure is 378 ft long, with two lanes in each direction and a center turn lane. In addition to traffic, the bridge also carries water, electric, and telecommunication utilities. It has 8-ft-wide shoulders, a 6-ft-wide sidewalk on the downstream edge of the bridge, and a 14-ft-wide multiuse pedestrian pathway on the upstream edge for a total bridge width of 99.5 ft.

Steel and concrete options of various span configurations were considered for the replacement bridge. Ultimately, a three-span, precast, prestressed concrete decked bulb-tee girder superstructure supported on reinforced-concrete-filled steel-pipe-pile extension bents was found to be the most cost-effective solution for the site.

Precast, prestressed concrete decked bulb-tee girders have been used in Alaska since the mid-1970s. In addition to being more durable than bridges with cast-in-place decks, bridges with predecked girder cross sections can be constructed rapidly, an important consideration given Alaska's cold climate and short construction season. The girders were fabricated at Concrete Technology Corporation's Tacoma, Wash., facility. This facility is located on a maritime waterway and has direct access from the fabrication floor to an awaiting barge. All 42 girders were shipped on one barge. The barge arrived at the Juneau dock where the girders were loaded on trucks and driven approximately ten miles to the bridge location. In Alaska, girders up to 165,000 pounds are commonly transported in this manner.

AKDOT&PF designs these sections to a zero-tension stress limit with the AASHTO LRFD Service III load combination using gross-section properties. The specified 28-day concrete compressive strength of these sections is typically a minimum of 7.5 ksi, with fabricators commonly achieving strengths of 10 to 12 ksi. This high-strength, high-durability concrete is used in the entire concrete section, including the monolithic deck. The three precast producers that provide decked girders for projects in Alaska (two in Anchorage, Alaska, and one in Tacoma, Wash.) have the capability to deflect (sag) the forms downward to offset prestress camber as a method to achieve the roadway profile grade needed for the roadway surface. Leveling inserts are provided in the girders to provide a method of adjusting differential camber between girders, if needed. High-strength (9 ksi) grout is used in the longitudinal keyways between the girders. The combination of using the zero-tension stress limit for design and high concrete strength has resulted in a very durable, nearly maintenance-free superstructure that is well suited to Alaska's severe environment.

For several decades, AKDOT&PF has used reinforced-concrete-filled steel

Completed first-stage pier using reinforced-concrete-filled steel pipe piles with reinforcement extended from top of cap to engage the diaphragm between girders.

Aerial view of the bridge with the first stage of construction nearly complete; the work trestle is on the left, and the old bridge is on the right.

pipe pile extension substructures (piles typically range from 2 to 4 ft in diameter for conventional bridges). Because this type of substructure does not require cofferdams, it can be built in less time than more traditional, pile-supported footings. The steel pipe acts as a stay-in-place form for the reinforced-concrete core and is included in the cross-sectional capacity of the members. The upper lengths of the pipe (exposed length and 10 ft below the minimum streambed surface) are hot-dip galvanized. AKDOT&PF requires the use of steel pipes that comply with either the American Petroleum Institute (API) 5L PSL2 X52 or ASTM A709 Grade 50T3 fabricated to API 2B or AKDOT&PF spiral (helical) weld specifications to provide superior seismic performance. Research performed at North Carolina State University developed strain limits of reinforced-concrete-filled steel tubes (RCFSTs) associated with the onset of pipe wall buckling and fracture (for more information, see the Concrete Bridge Technology article on RCFSTs in this issue of *ASPIRE*® on page 32). These composite concrete-steel sections are stiffer, stronger, and more ductile than conventional reinforced concrete or hollow steel members and are better able to accommodate large lateral demands from ice, earthquakes, and vehicle collisions.

The project included construction of paths below both sides of the Brotherhood Bridge to allow pedestrians and bicyclists to safely cross under the highway along the riverbanks. Mechanically stabilized earth walls are utilized at each abutment to improve pedestrian access under the bridge. The bridge abutments are supported by fourteen 2-ft-diameter concrete-filled pipe piles under each cap beam to accommodate the large seismic demands, including predicted pile-pinning action and lateral soil movement.

Above the bedrock at the site was 290 ft of very loose soils. Based on the two-dimensional, site-specific seismic analysis, the five 48-in.-diameter pipe piles driven to bedrock and partially filled with concrete were found to be the most cost-effective foundation type for the bridge piers. Only the top 85 ft of the pipe piles are filled with reinforced concrete. The design required concrete to be placed below the ground line to a point where the moment is less than half the maximum plastic hinging moment accounting for the effects of scour, liquefaction, and other factors that lower the plastic hinge location.

Because the AKDOT&PF right-of-way is relatively narrow at this crossing, staged half-width construction was selected to allow traffic during construction. About one-third of the new bridge was built upstream of the old steel girder bridge without affecting traffic. Once the first stage of construction was complete, vehicular and pedestrian traffic was routed over the new bridge. The old bridge was demolished, and the steel was sent to a recycling facility outside of Alaska. The rest of the new bridge was constructed and traffic was placed in the final configuration.

Since construction was staged, full designs were completed for the two bridge configurations, including evaluation of the seismic response of both stages, to ensure safe and adequate performance during the entire construction process.

During construction of the bridge, a *jökulhlaup* occurred, carrying large amounts of wood and debris. Fortunately, the bridge contractor was able to quickly respond to the unexpected event and removed debris around the work trestle during the outburst and for several days after it.

The deck and cast-in-place approach slabs are covered with a waterproofing membrane and 4 in. of asphalt concrete. Concrete formliner replicas of the ANB medallions were fabricated and used in the wingwalls. Cast-in-place end, pier, and intermediate diaphragms are used in the superstructure. The abutments employ a semi-integral abutment concept that results in a jointless bridge and subsequently reduced maintenance needs.

The total cost of the project, including demolition of the existing bridge, was approximately $11 million, which corresponds to about $294 per square foot of bridge deck area. Conventional highway bridges in Alaska typically cost between $300 and $350 per square foot. Considering the use of staged construction, decorative railing, long piles, and poor soil conditions, the Brotherhood Bridge proved to be a very cost-effective structure. The high-strength precast concrete decked bulb-tee girders will provide a durable bridge requiring minimal maintenance over the structure's design life.

Elmer Marx is a senior bridge design engineer with the Alaska Department of Transportation and Public Facilities in Juneau.

Aerial view of the bridge carrying traffic while the second stage of construction was underway.